EnsAD
EnMAP – satellite-based algae detection for Copernicus und downstream services

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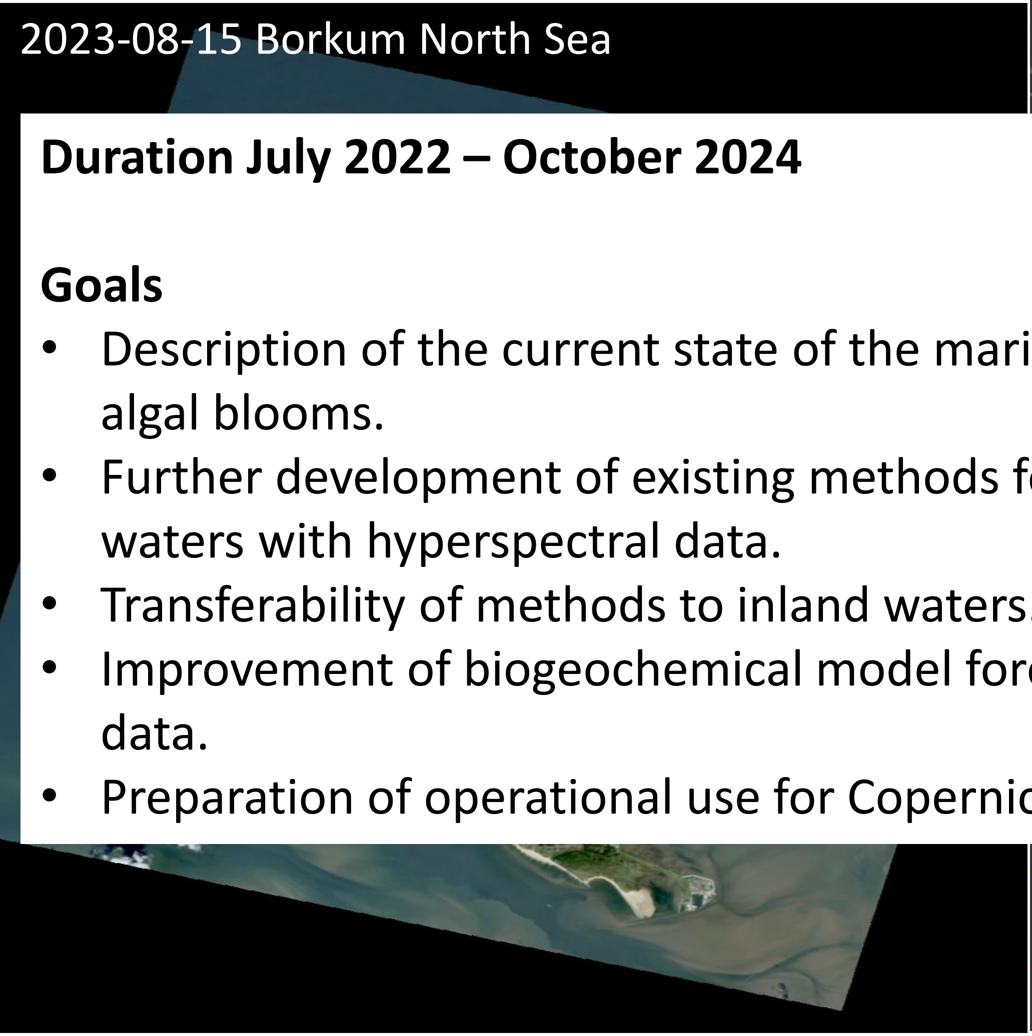
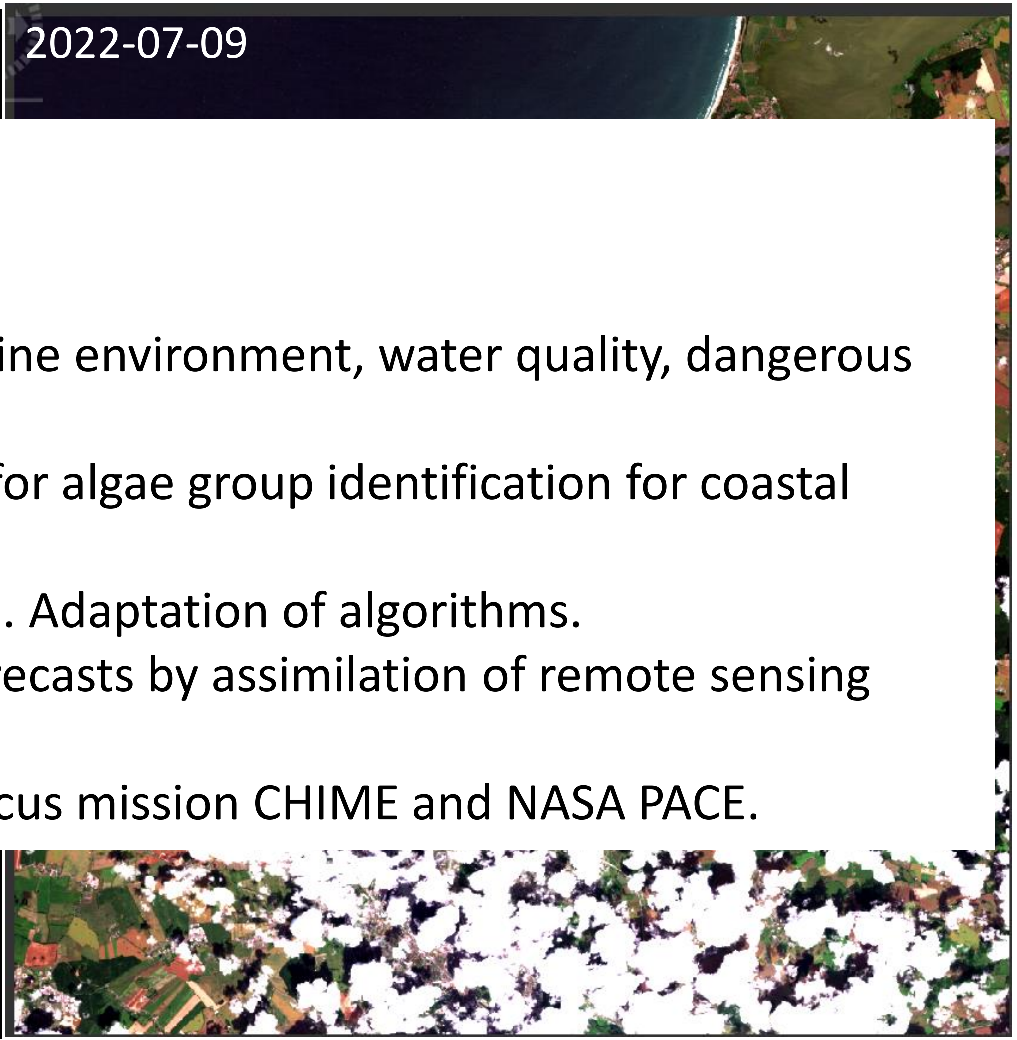
funded by Federal Ministry for Economic Affairs and Climate Action

EnsAD **En**MAP - **s**atellite-based **a**lgae **d**etection for Copernicus und downstream services

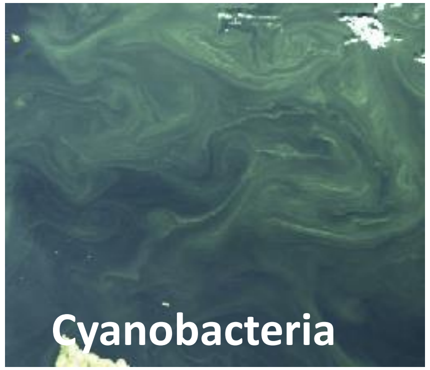




Duration July 2022 – October 2024

Goals

- Description of the current state of the marine environment, water quality, dangerous algal blooms.
- Further development of existing methods for algae group identification for coastal waters with hyperspectral data.
- Transferability of methods to inland waters. Adaptation of algorithms.
- Improvement of biogeochemical model forecasts by assimilation of remote sensing data.
- Preparation of operational use for Copernicus mission CHIME and NASA PACE.



EnsAD – Building blocks and algorithms for EnMAP

Selection/Testing PFT Algorithm

- ***Forward Model Inversion*** [1,2]
- Phaeocystis identification[3]
- ?

Validation

- **BSH on ship measurements**
- **GLORIA**[4]

Application PFT Algorithm

- **Machine Learning**

Model integration

- HBM-ERGOM[5]

Selection/Testing PFT Algorithm:

- Tuning of bio-optical model
- Splitting the brown group in large vs small algae
- Adding/removing free parameters
- Speed adjustments for full inversion

Validation:

- Testing full inversion on other satellite sensors (convolving GLORIA insitu data with SRFs)
- Validate against species composition from in-situ data

Application PFT Algorithm:

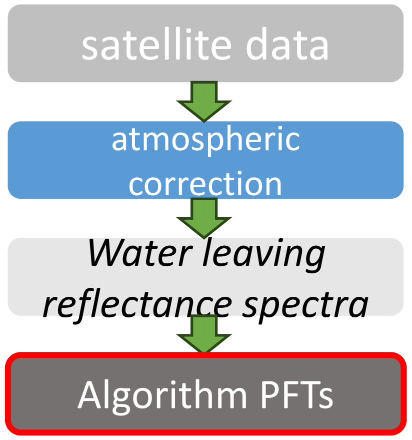
- Bridging the gap between model and satellite data (smooth spectra vs spectral noise)
- Application to full scenes

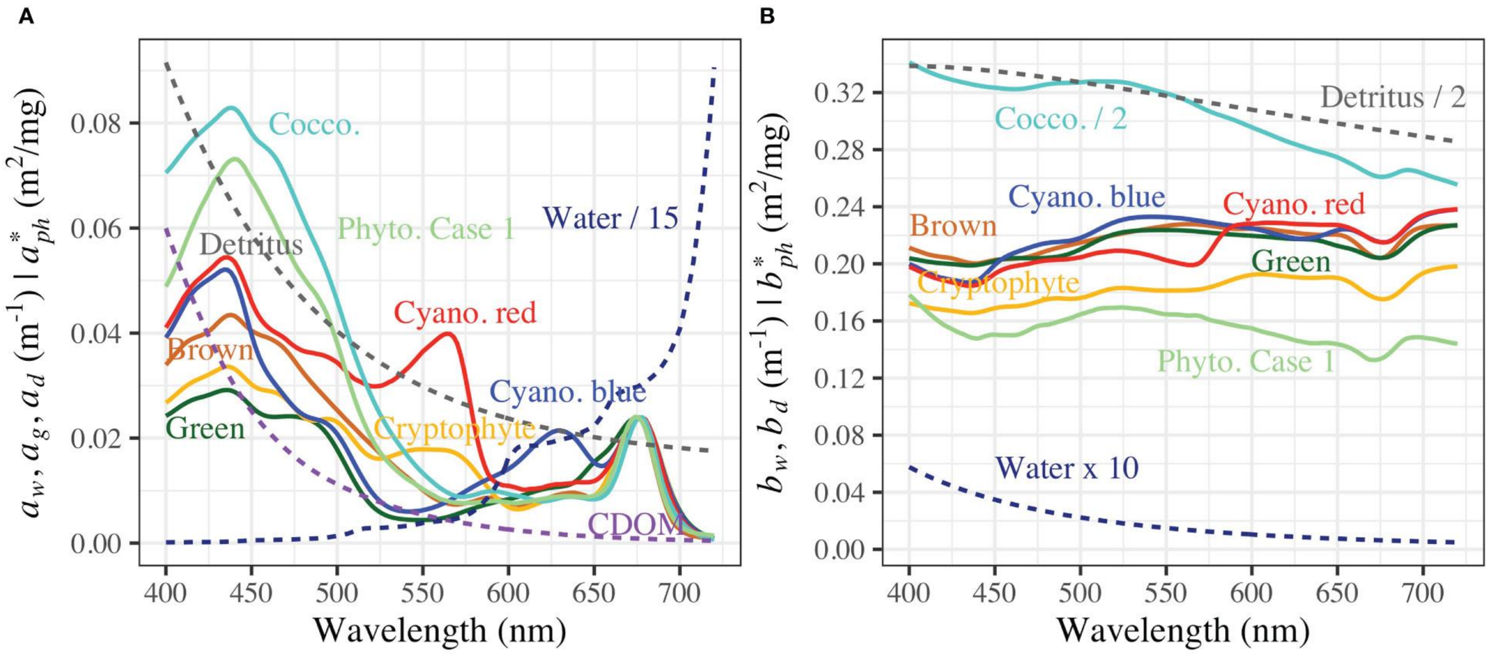
Model integration:

- Create input for assimilation:
  - weekly data for North Sea and Baltic Sea 5km (1km) grid.
  - Algae Group composition (conc.)
- Start values from OLCI?
- Preparing for PACE data

1) *Shun Bi, Martin Hieronymi, Rüdiger Röttgers, Bio-geo-optical modeling of natural waters, Frontiers in Marine Science. 2023.*
2) *Chase et al (2017). J. of Geophysical Research: Oceans, 122, 9725–9743*
3) *Lavigne et al (2022). RSoE https://doi.org/10.1016/j.rse.2022.113270*
4) *Lehmann, M.K., Gurlin, D., Pahlevan, N. et al. GLORIA - A globally representative hyperspectral in situ dataset for optical sensing of water quality. Sci Data **10**, 100 (2023). https://doi.org/10.1038/s41597-023-01973-y*
5) *HBM-ERGOM - Thorger Brüning, Xin Li, Fabian Schwichtenberg, Ina Lorkowski 2021, HN 118, Seite 6–15, DOI: 10.23784/HN118-01*

EnsAD Algorithm Phytoplankton ~~Functional~~ Optical Types





From:
Shun Bi, Martin Hieronymi, Rüdiger Röttgers, Bio-geo-optical modeling of natural waters, Frontiers in Marine Science. 2023.

Forward Model for iterative inversion of water leaving reflectance
with **6 algae groups**:

- brown group
- green group
- Cryptophyta
- Cyanobacteria, blue
- Cyanobacteria, red
- Coccolithophors

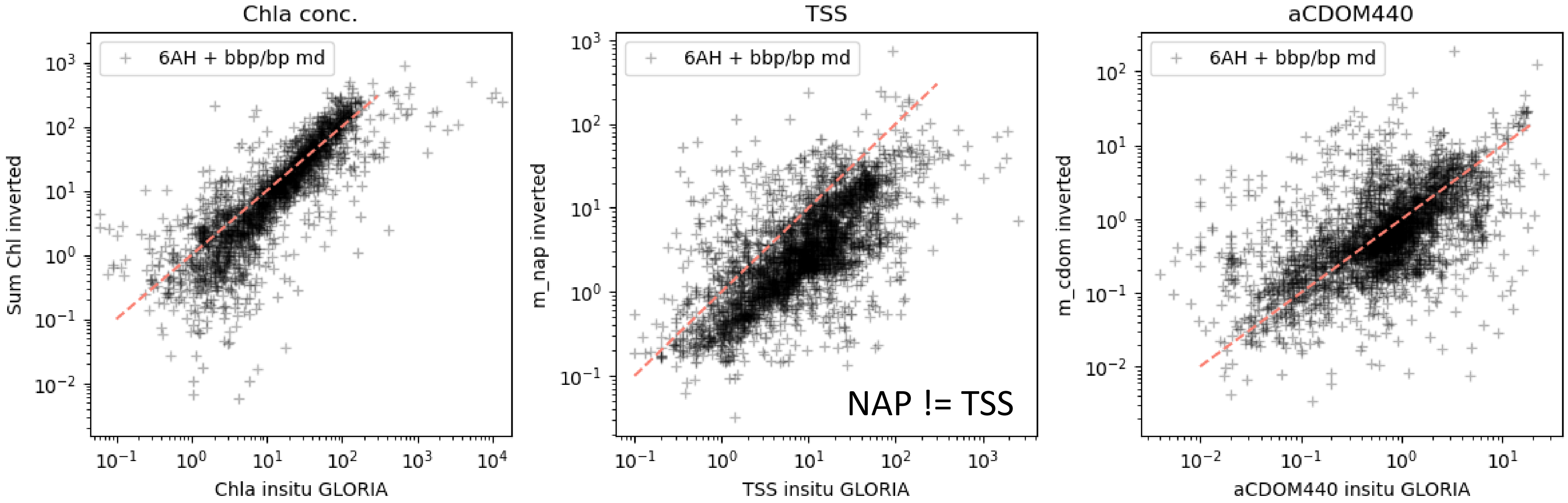
Forward Model includes:
- **specific absorption** of phytoplankton groups
- **specific scattering** of phytoplankton groups

Free parameters (10)

- *phytoplankton concentration per group,*
- *aCDOM 440, slope CDOM,*
- *NAP*
- *Fluorescence peak*
- optional: bbp/bp mineralic detritus
- optional: bbp/bp biogenic detritus

Inversion on spectrum between 400 and 710nm
Minimum range: 440 to 710 nm
IOPs for pure water: 250 - 800nm
Specific absorption/scattering of phytoplankton 400-720nm
Start values and **ranges** estimated from band ratios (*O'Shea et al. 2023*)

EnsAD Algorithm **P**hytoplankton **O**ptical **T**ypes



Input: GLORIA insitu spectra convolved with EnMAP SRF (N=3034), with Rrs + Chl + TSS + aCDOM
Inversion results from model 6AH + md (11 free parameters)

6AH + bbp/bp md	Chl	TSS	aCDOM
Slope	1.233	0.937	0.995
R^2	0.831	0.683	0.571
eps	-19.37	-65.62	-8.01

Results

- No result for chl. conc: 111 of 3034
- Underestimation of TSS is plausible. Forward model uses NAP (non algal particles), while TSS is total suspended substance.
- Overall good agreement in total chlorophyll concentration

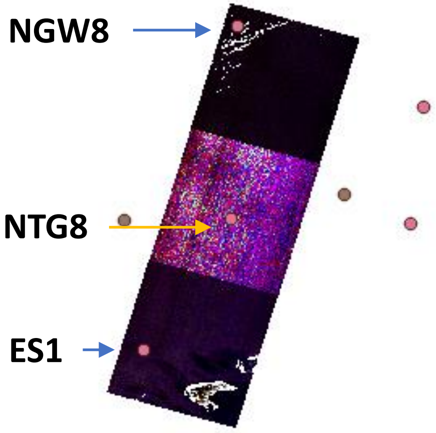
median symmetric accuracy

$$\epsilon = 100 * (\exp median(|\log_e Q_i|) - 1)$$

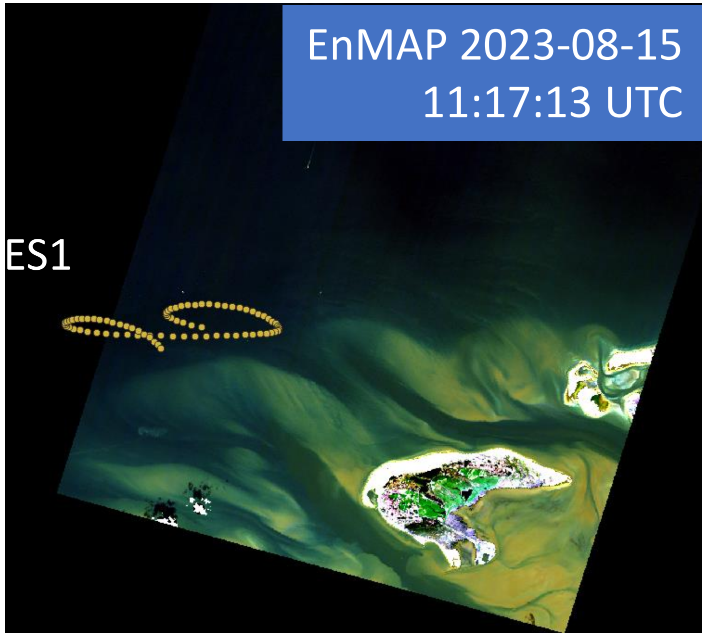
with $Q_i = y_i / x_i$

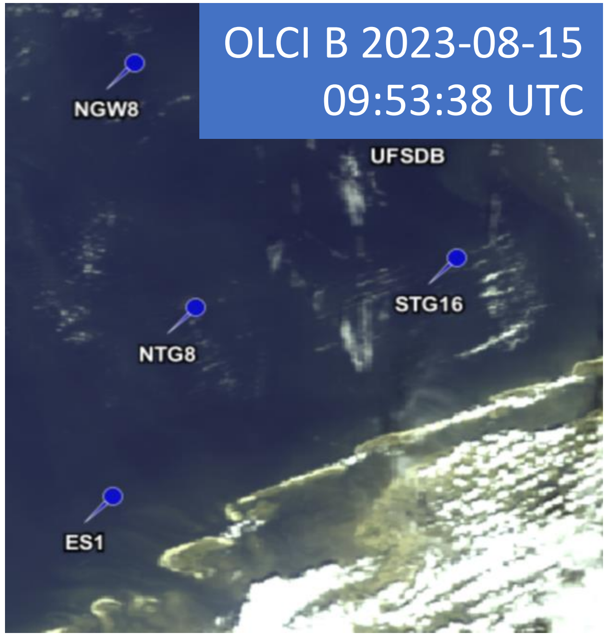
(from *O'Shea et al. 2023*)

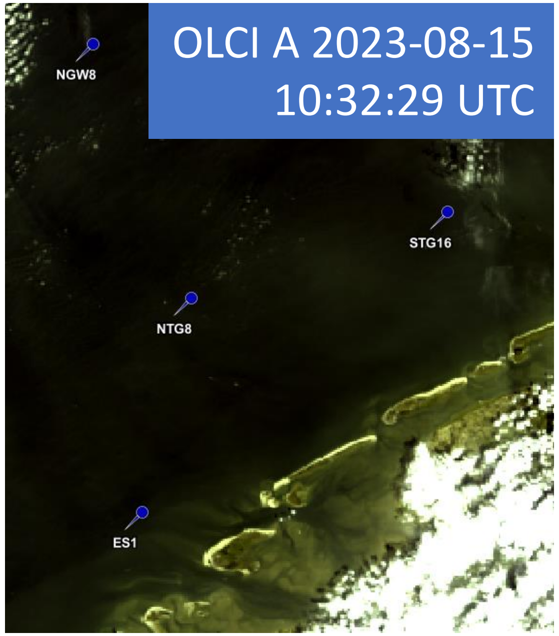
Inversion Analysis EnMAP Borkum 2023-08-15

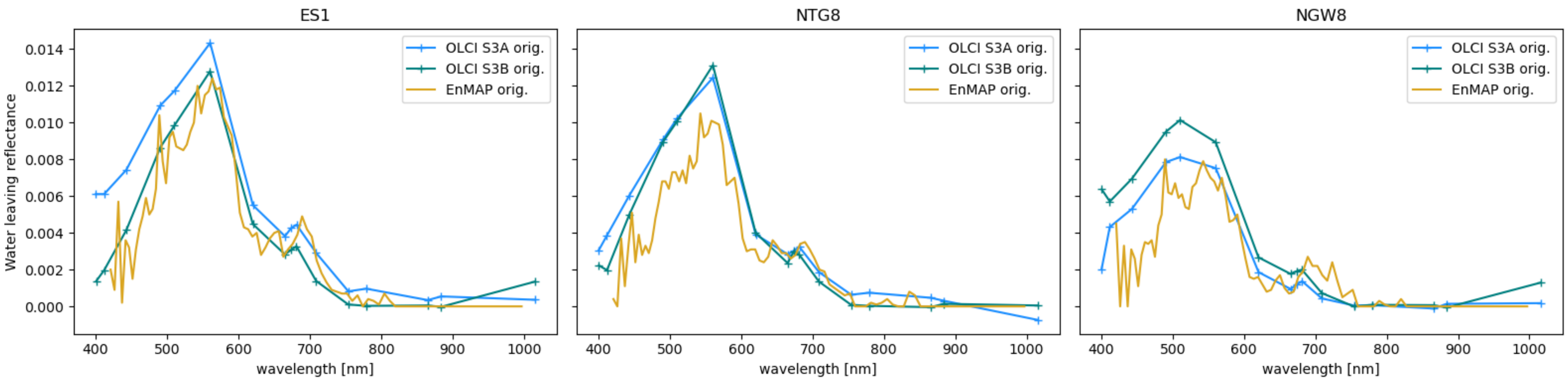


Overview of EnMAP tiles and Positions of insitu data points





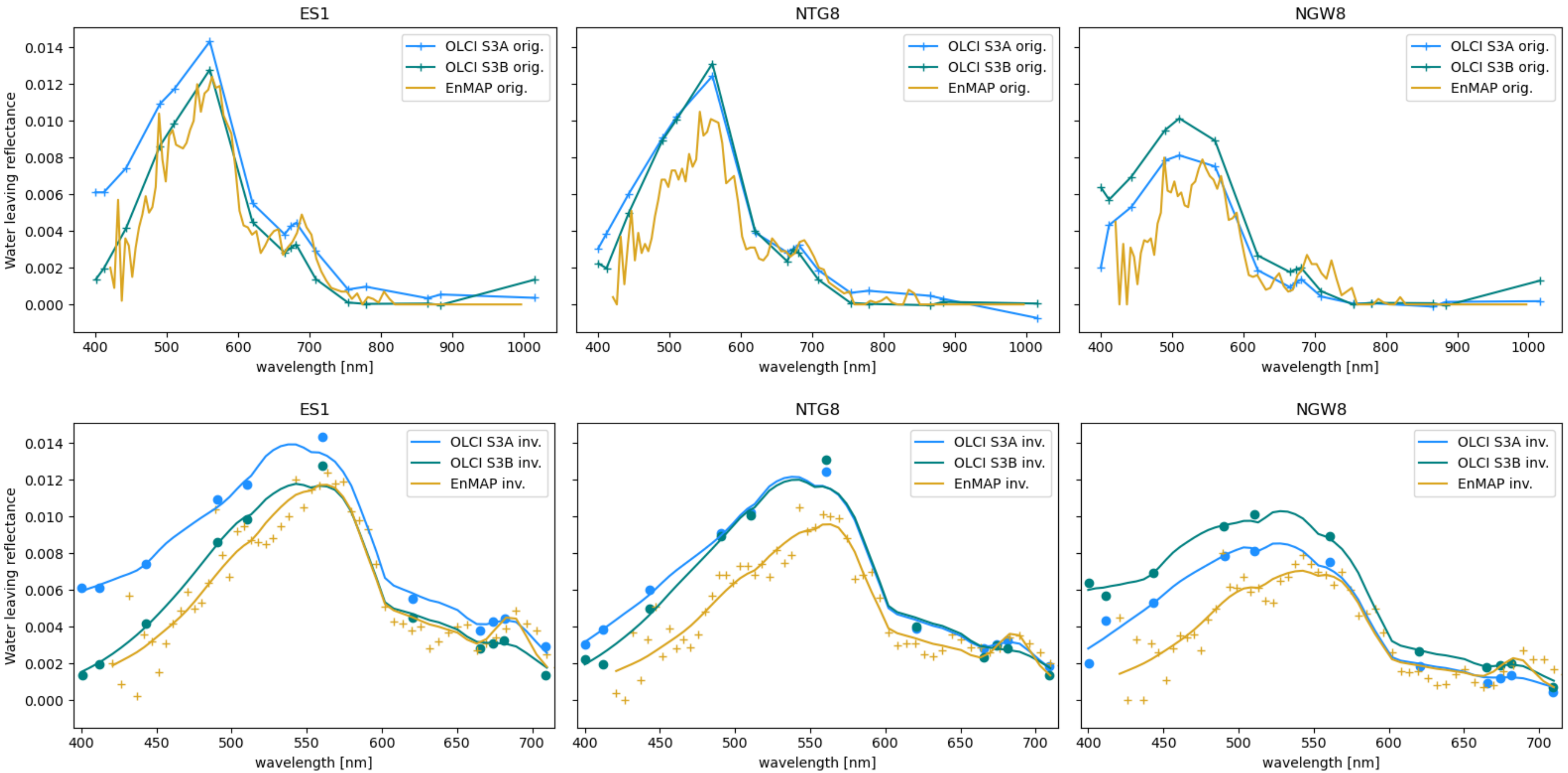




Extracts

- EnMAP L2A product version 01.03.03, Standard AC ('turbid')
- OLCI S3A/S3B L2A Water product (IPF coll. 3)

Inversion Analysis EnMAP Borkum 2023-08-15



ORIGINAL

Inversion Forward Model

ES1	NAP	aCDOM 440	Brown	Green	Cyano blue	Cyano red	Coccol.
OLCI A	3.6	0.016		1.74	1.28		0.175
OLCI B	2.5	0.28		0.307			0.497
EnMAP	0.647	0.361	3.86			0.261	

NTG8	NAP	aCDOM 440	Brown	Green	Coccol.
OLCI A	2.15	0.089		1.98	0.38
OLCI B	2.35	0.198		1.51	0.19
EnMAP	0.75	0.327	3.422		

NGW8	NAP	aCDOM 440	Brown	Green	Cyano blue	Coccol.
OLCI A	0.77	0.058		0.95		0.15
OLCI B	1.37	0.01		0.49	0.99	
EnMAP	0.227	0.234	1.601			

Machine Learning in EnsAD (tbd)

AC corrected, spectrally noisy data

↓ Machine learning

Smooth water leaving reflectance
or: total phytoplankton absorption

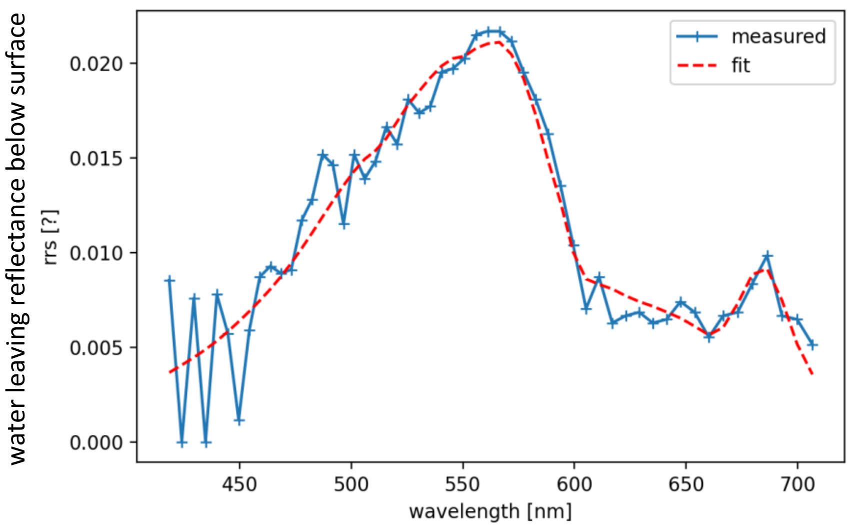
↓ Machine learning

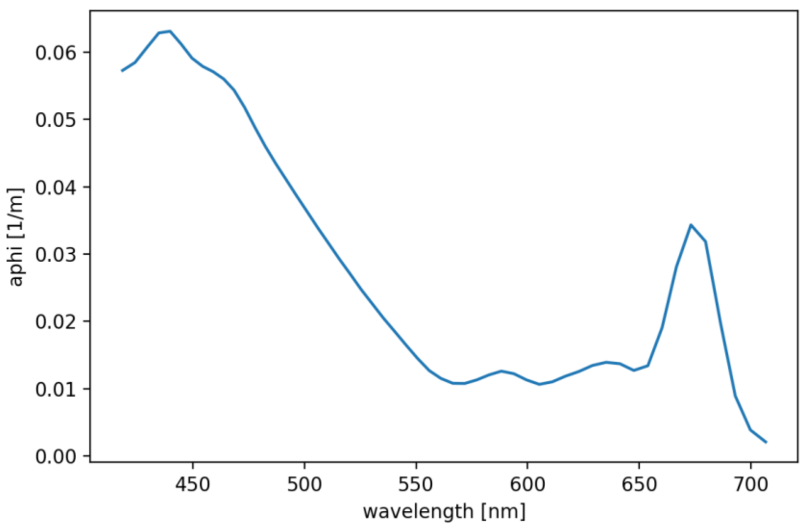
IOPs, phytoplankton composition
on full scene

ML "Smoothing Rhow Spectra"
Training data: Extracts from EnMAP L2A data, inverted with iterative forward modelling
ML-technique: ?
Input: EnMAP L2 data (400-710nm)
Output: smooth rhow spectrum OR total phytoplankton absorption spectrum
Validation: ? – Trying to achieve full optical closure with the forward model, cannot account for ambiguity of IOPs and rhow

ML "Full Scene Application 1"
Training data: from Forward Model
ML-technique: ?
Input: smooth rhow spectrum
Output: IOPs (NAP/TSS, aCDOM, phytoplankton conc. per group)
Validation: ?

ML "Full Scene Application 2"
Training data: from Forward Model
ML-technique: ?
Input: phytoplankton total absorption spectrum
Output: phytoplankton conc. per group
Validation: ?





*Output **iterative inversion procedure**: fitted rhow, all spectral absorption and scattering components (here total phytoplankton absorption), NAP, aCDOM, phytoplankton concentration per group*

EnsAD Literature

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